
Experiences at T2K

CCQE-like measurement

Andy Furmanski

Introduction

- Hi, I'm Andy, a new postdoc at Manchester
- I am now a MicroBooNE collaborator
 - With an interest in neutrino cross sections
- I'll discuss my previous work at T2K, and some thoughts about what I'd like to do with MicroBooNE



Me behind the worlds third-tallest buddha (close to J-PARC in Japan)

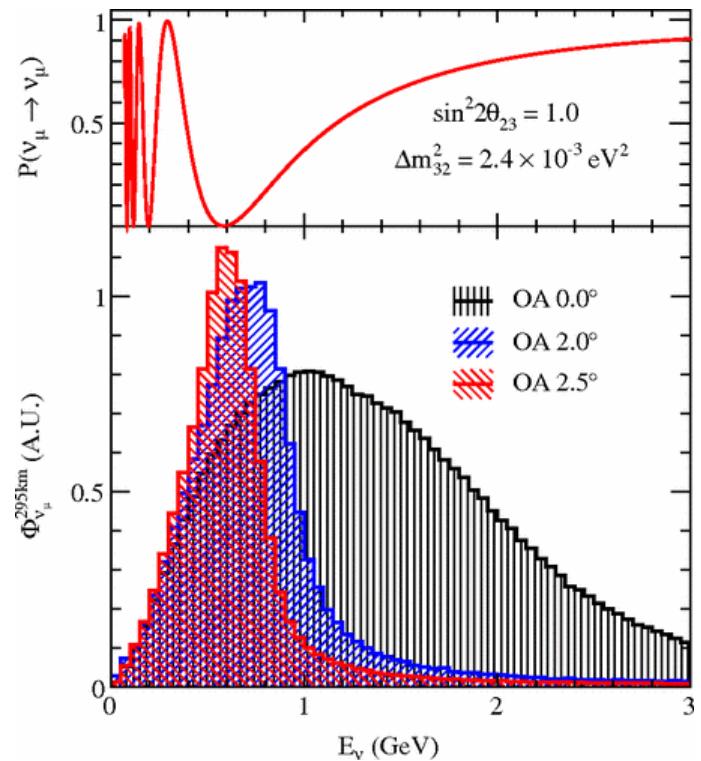
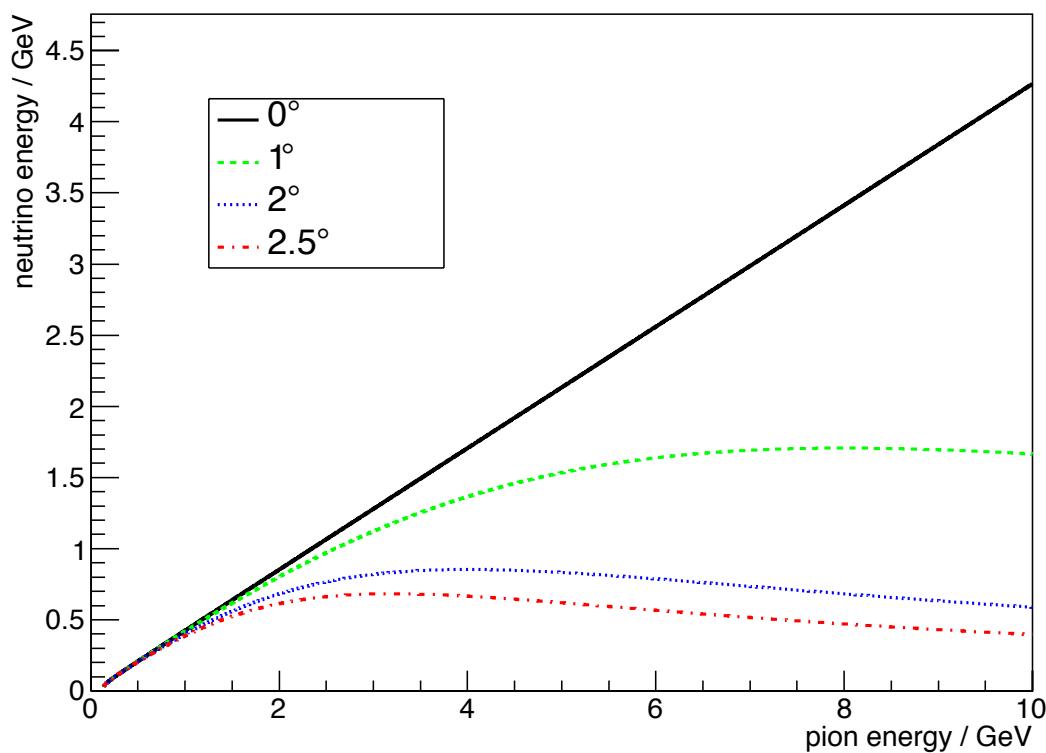
T2K

- Long baseline oscillation experiment in Japan
- Beam runs from J-PARC on east coast
 - To Super-Kamiokande near Toyama
- Measuring ν_e appearance in a ν_μ beam



Beam

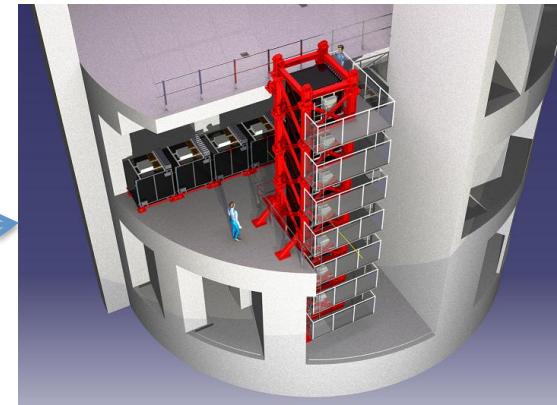
- T2K uses an off-axis beam
- Narrow-band with a peak around 0.6 GeV
- High purity ν_μ



Detectors

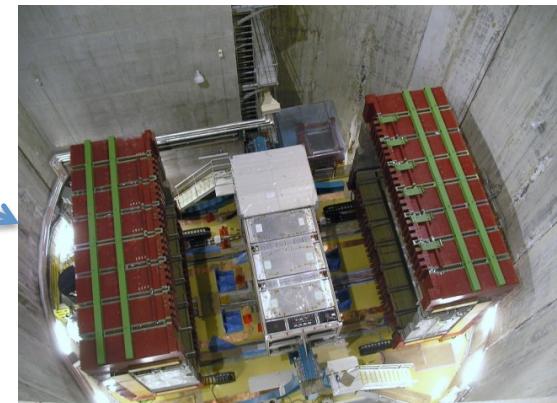
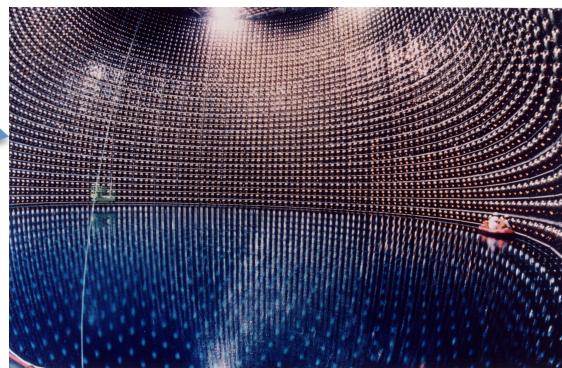
- Near detectors at 280 m

- INGRID: on-axis
 - ND280: off-axis



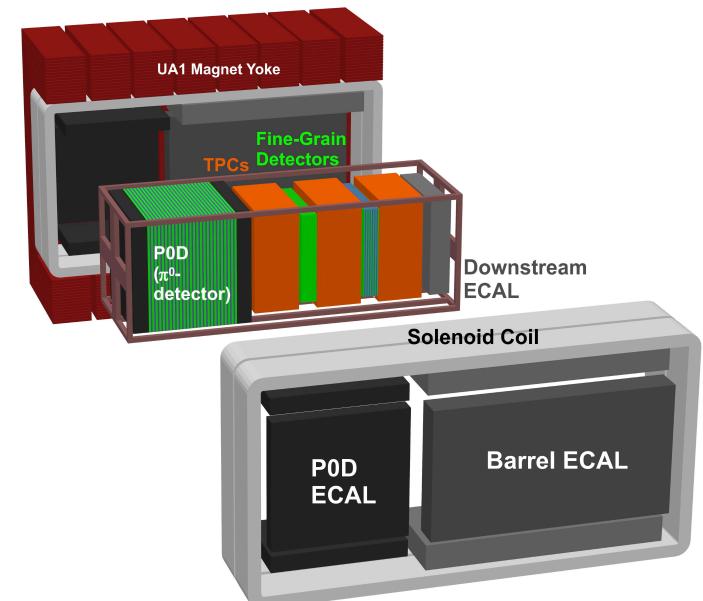
- Far detector at 295 km

- SK



ND280

- Off-axis near detector
- Important features:
 - Plastic scintillator target (FGD)
 - Argon gas TPC for tracking
 - 0.2 T magnetic field
- Also
 - Water targets
 - ECal to pick up photons



The measurement

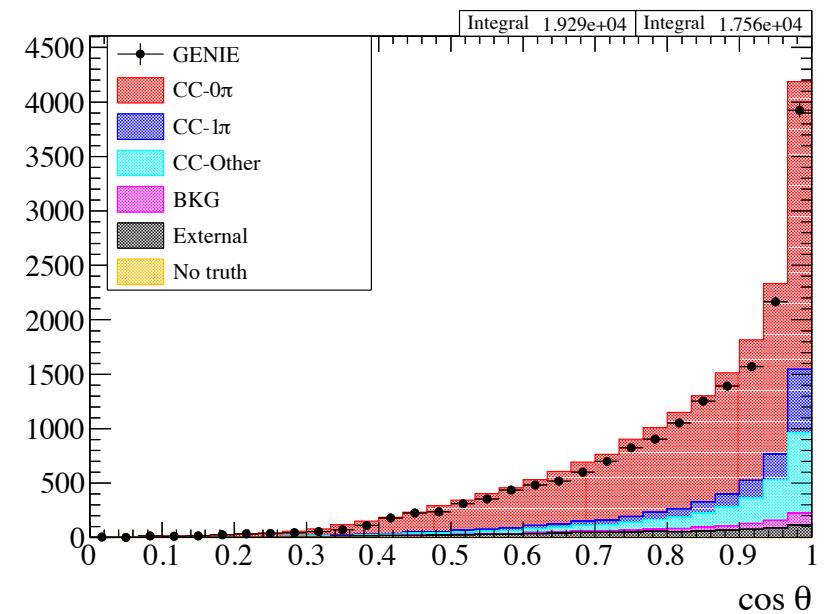
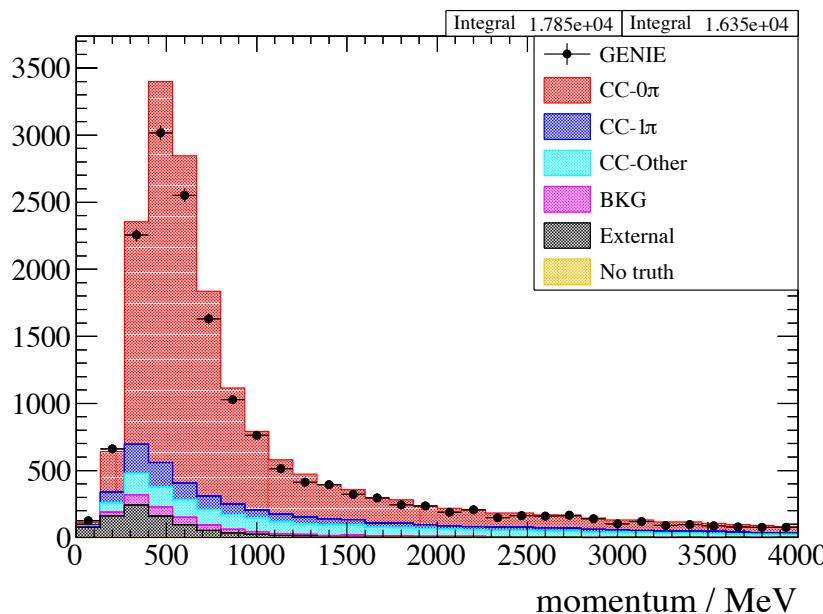
- We want to measure the CCQE cross section
 - But we are worried about multinucleon processes
 - And we don't trust our FSI model
 - Our measurement cannot depend on the signal model
- Model independent
- We define our signal as CC0 π
 - This is ~85% CCQE
 - Defined by detector topology
- Topology defined
- Don't trust our ability to determine the neutrino energy
 - Measure in detector variables
 - Don't correct for flux in each bin, just scale by total flux
- Flux-integrated

CCQE-like selection

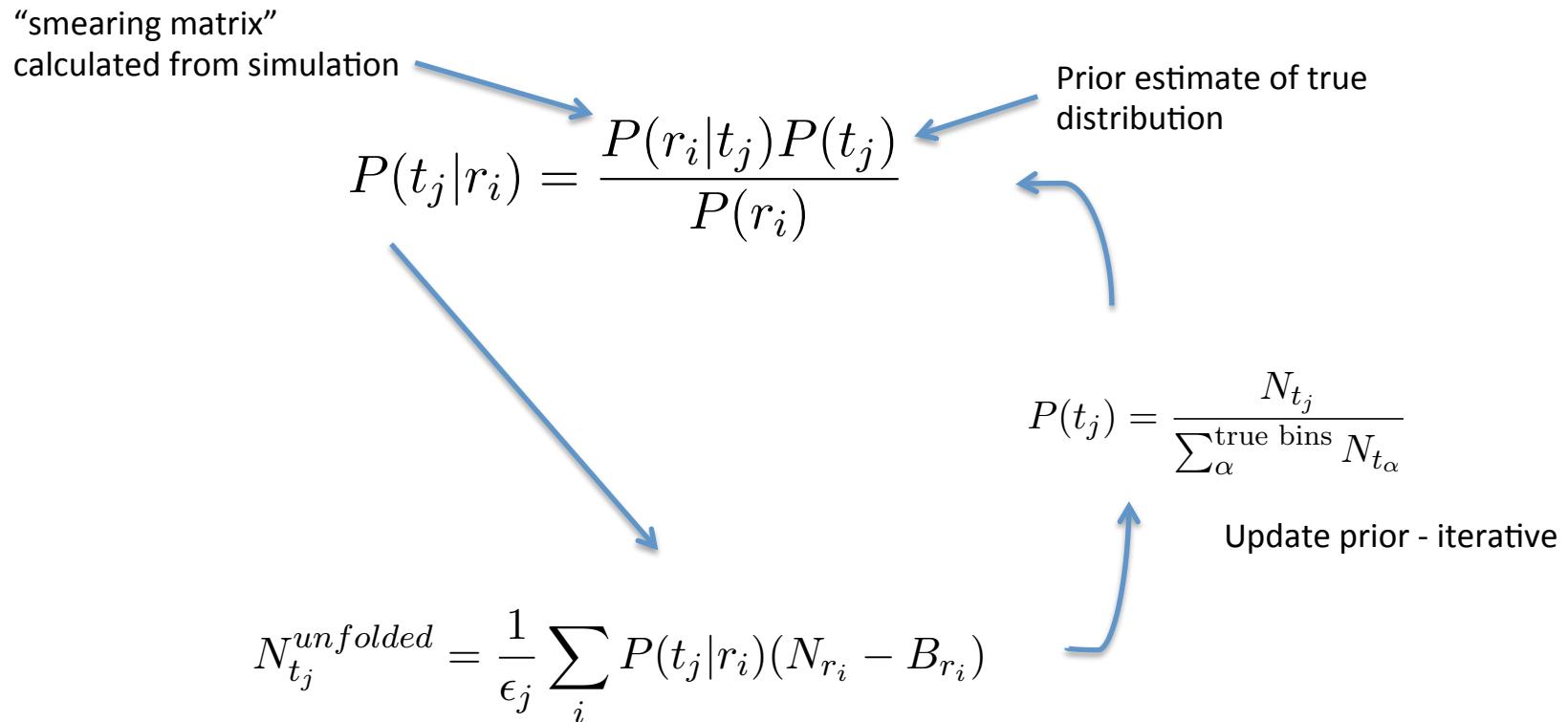
- Select a muon candidate
 - Highest momentum negative track
 - Muon-like (dE/dx in TPC)
 - Quality cuts, broken track cuts, etc
- Reject pions
 - Pion-like TPC tracks
 - Pion-like FGD-only tracks
 - Decay electrons
 - Electron-like tracks in TPC (from π^0 decay)
- Completely proton-inclusive

Sample

- 72% pure CC0pi (according to NEUT MC)
- Poor coverage at low momentum
- Poor coverage at high/backwards angles
 - Due to detector geometry



Bayesian unfolding

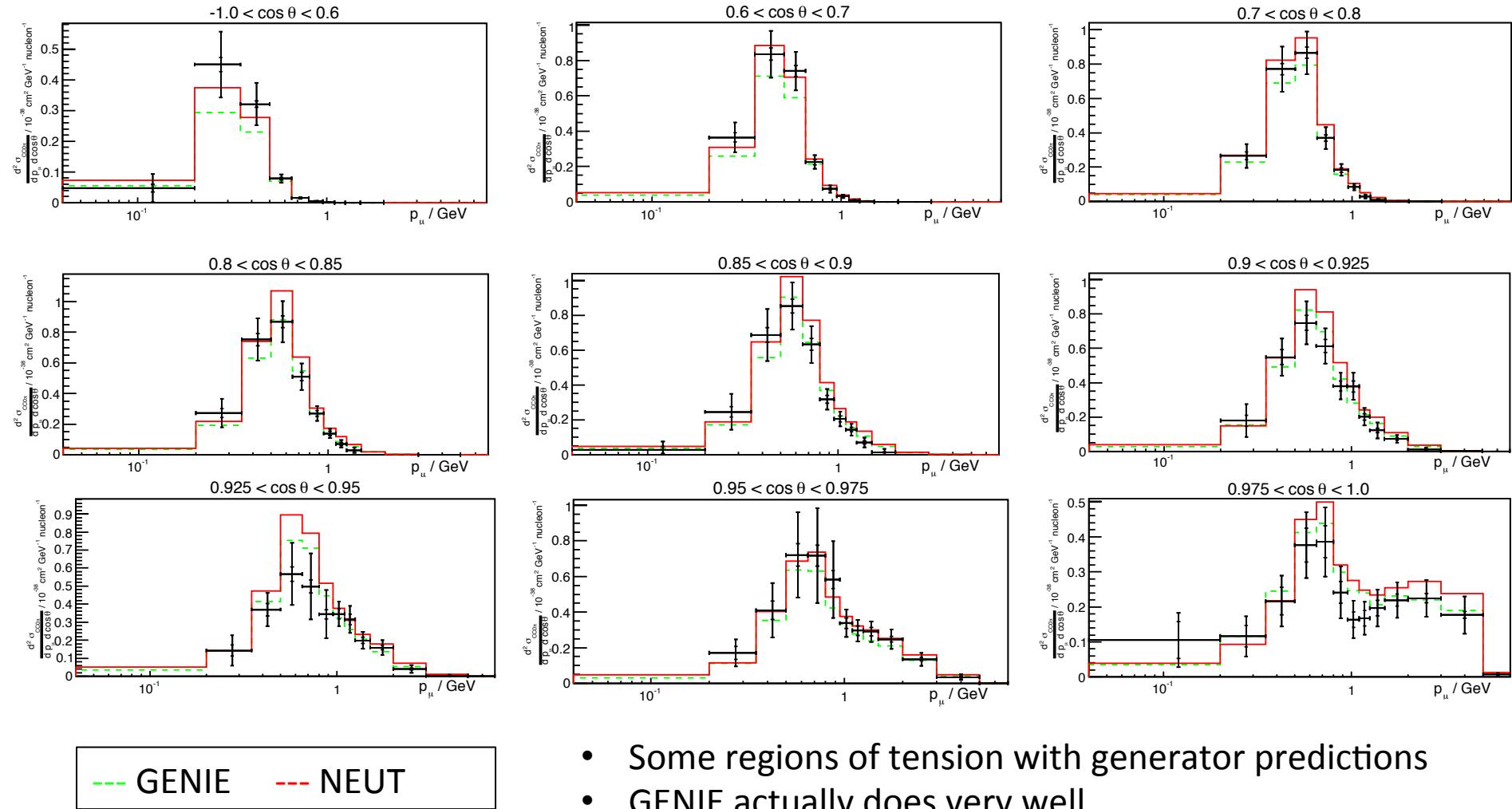


- Converts from reconstructed variables to true variables
- Works in arbitrary dimensions, provided the quantities are binned
- In this case we use 2D ($p, \cos\theta$)

Uncertainties

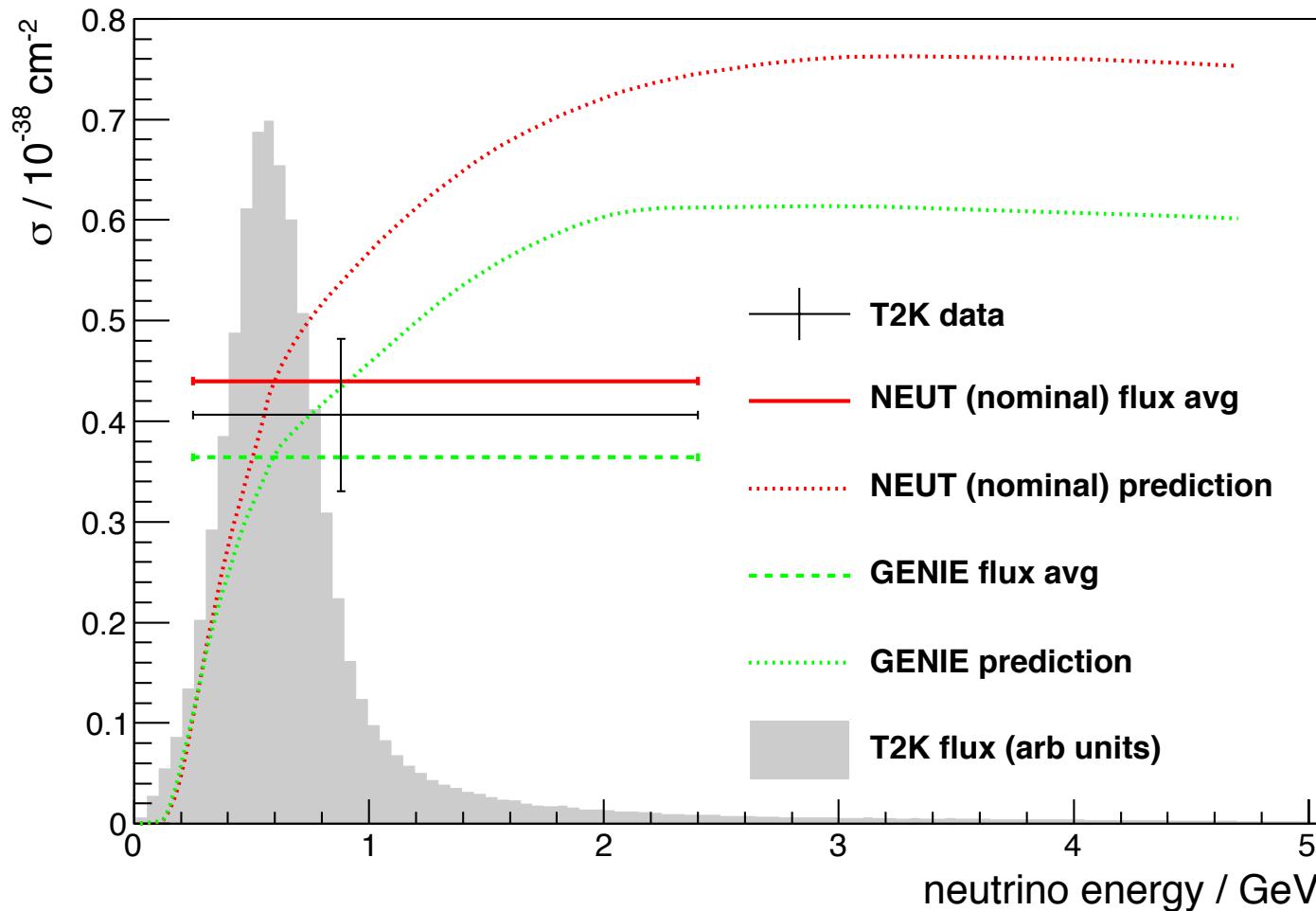
- Estimate uncertainties with toy experiments
 - Vary inputs -> unfold -> see spread of results
- Dominant uncertainty is **11% flux normalisation**
 - Completely correlated across all bins
- Then uncertainties on **background** at **~5%**
- Largest detector uncertainty is pion secondary interactions
 - Changes the rate of missed pions

Differential results



- Some regions of tension with generator predictions
- GENIE actually does very well

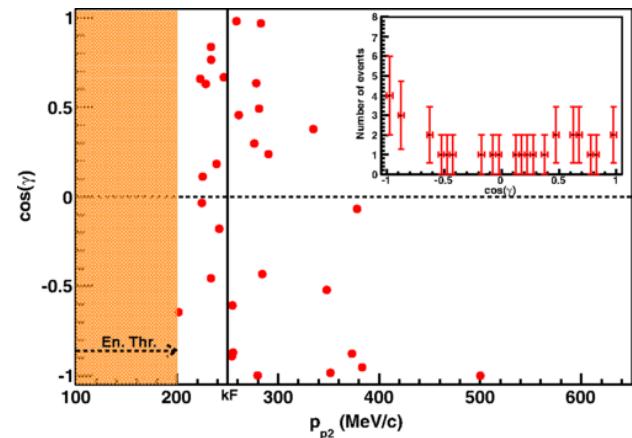
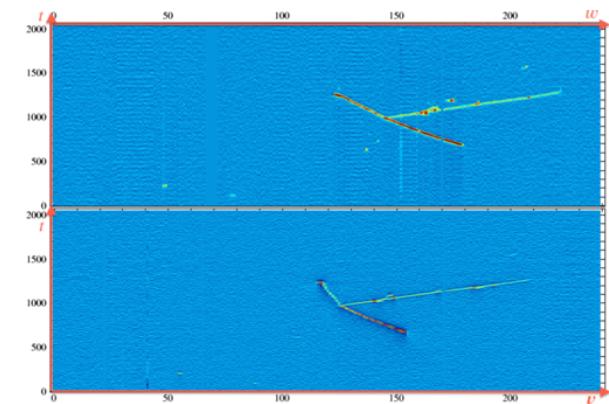
Integrated results



Hopes for MicroBooNE

Protons!

- ND280 had a number of limitations
 - Very high threshold for tracking particles
 - Limited phase space due to geometry
- MicroBooNE will do much better in both cases
- ArgoNeuT have some very interesting events
 - Back-to-back protons
- Much higher statistics at MicroBooNE!

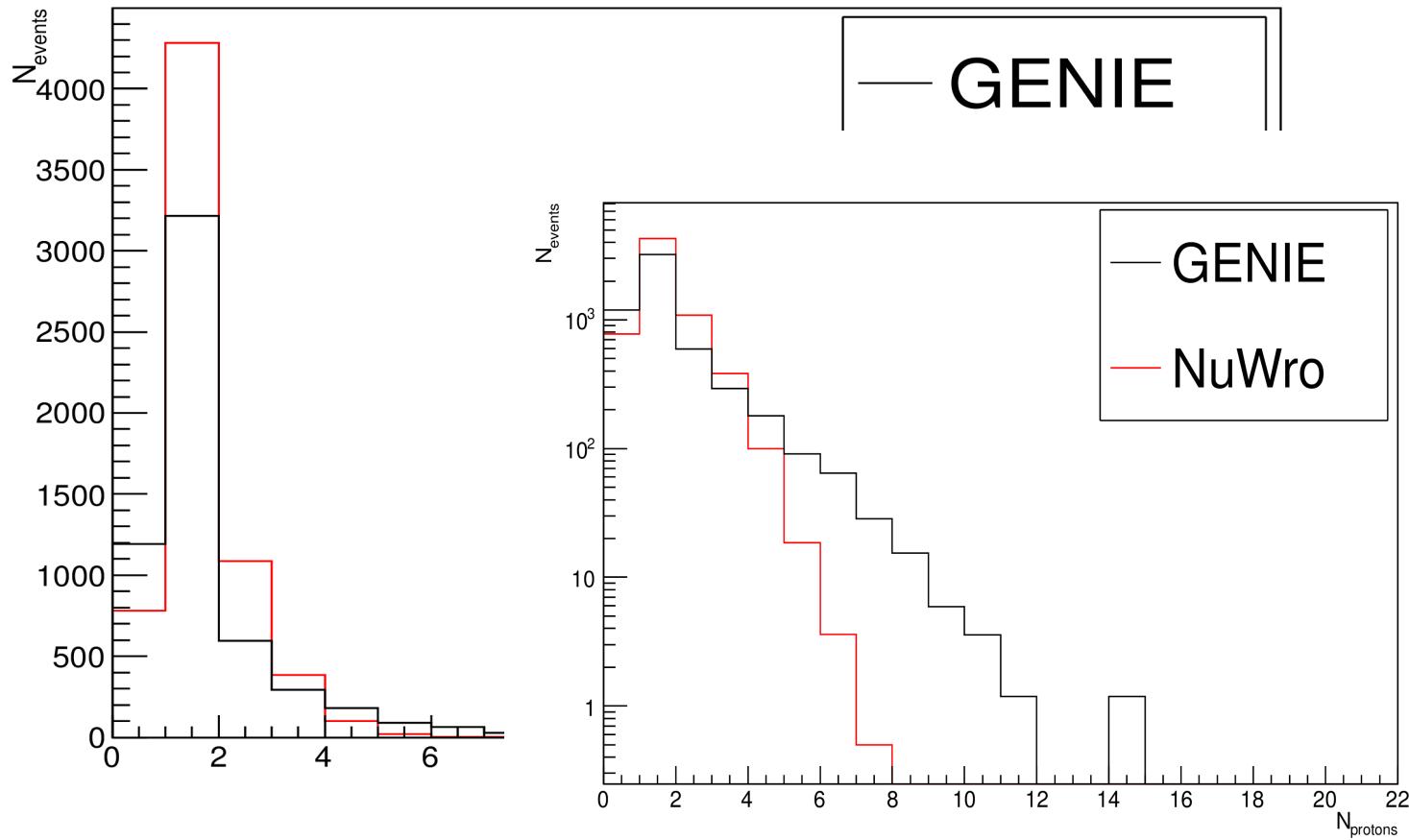


Generator studies

- Considering two generator predictions
 - GENIE (in MCC5, 2.8.6?)
 - NuWro (includes short-range correlations, MEC)
- 5.5E19 POT – statistical uncertainties shown
- Only considering true CC0pi events
- Only considering protons above 200 MeV
 - Conservative estimate for threshold for tracking
- We will see the generators make very different predictions!

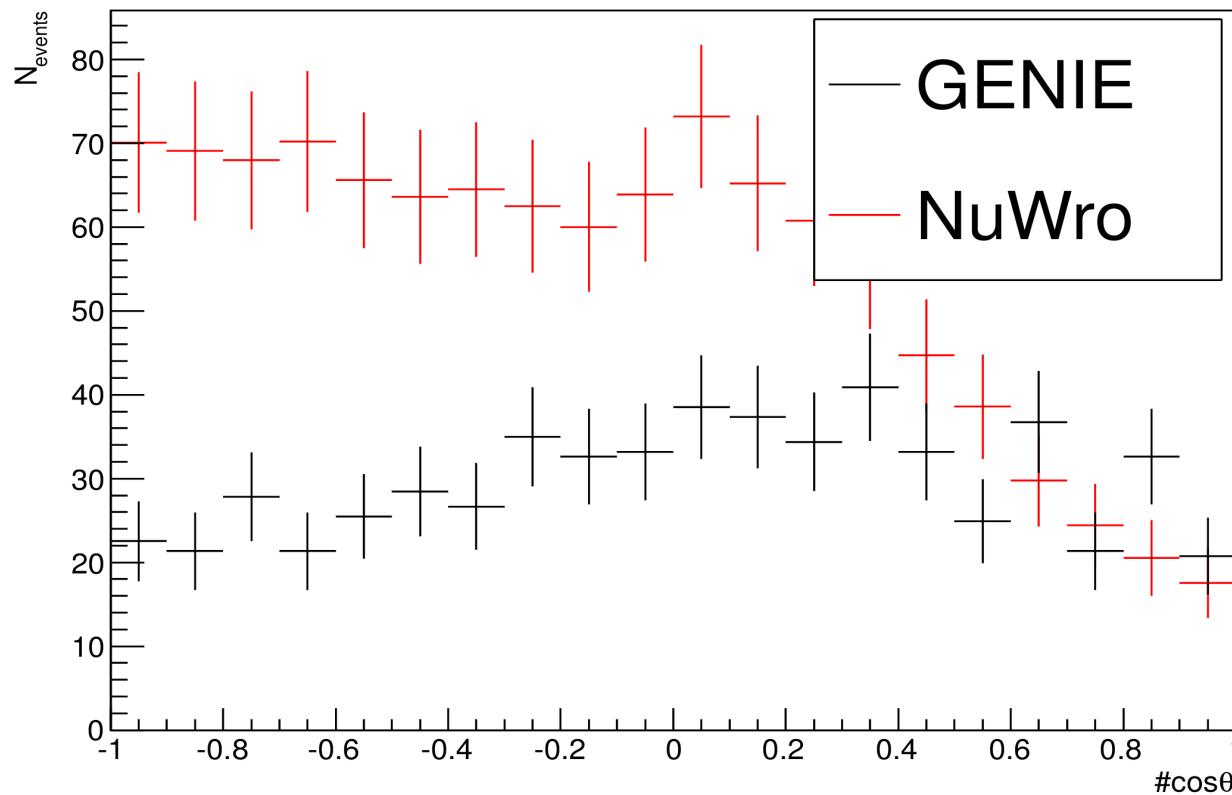
Number of protons

- Very different predictions in every bin



Lab frame proton-proton angle

- For the case where there are 2 protons
- GENIE second protons look isotropic – all from FSI
- NuWro has a suppression at low opening angles, or enhancement at high angles
 - Consistent with some additional process



Further proton studies

- Show separate contributions (CCQE, MEC, etc)
- Study other interesting variables
- Is the reconstruction capable enough yet?
- Selection efficiencies, backgrounds, etc
- Lots more to do!

Conclusions

- Generators make very different predictions for the spectra of protons
- MicroBooNE can make some very interesting measurements with not much data!
- I believe these will be extremely interesting to the community